Research report:

Dynamic Optimization of the Estimation of Dissolved Oxygen for First Order Streams.

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Research plan:

- **Explaining the topic**
- **Justifying the choice of this topic**
- **Explaining the problem to optimize**
- **Explaining the solution**
- **Implementation in Morocco**
- **Enlargement perspectives for the optimization method**
- **Will a project optimization be more efficient If it’s by a technical office or a big company?**
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Explaining the topic

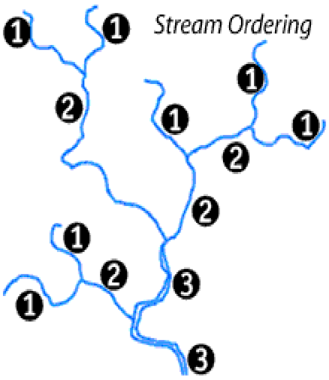
- ## Definitions:

Dissolved oxygen : It's a measure of how much oxygen is dissolved in the water - the amount of oxygen available to living aquatic organisms. The amount of dissolved oxygen in a stream or lake can tell us a lot about its water quality.

Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, whereas stagnant water contains less. Bacteria in water can consume oxygen as organic matter decays. Thus, excess organic material in lakes and rivers can cause eutrophic conditions, which is an oxygen-deficient situation that can cause a water body to "die." Aquatic life can have a hard time in stagnant water that has a lot of rotting, organic material in it, especially in summer (the concentration of dissolved oxygen is inversely related to water temperature), when dissolved-oxygen levels are at a seasonal low. Water near the surface of the lake– the epilimnion– is too warm for them, while water near the bottom–the hypolimnion– has too little oxygen. Conditions may become especially serious during a period of hot, calm weather, resulting in the loss of many fish. **(1)**

First Order streams: When diagramming stream order, scientists begin by identifying the first-order streams in a watershed. First-order streams are perennial streams, streams that carry water throughout the year--that have no permanently flowing tributaries. This means no other streams "feed" them.

Once the first order streams are identified, scientists look for intersections between streams. When two first-order streams come together, they form a second-order stream. When two second-order streams come together, they form a third-order stream. And so on. However, if a first-order stream joins a second-order stream, the latter remains a second-order stream. It is not until one stream combines with another stream of the same order that the resulting stream increases by an order of magnitude. See the diagram to the right. **(2)**



Justifying the choice of this topic

Environmental engineering is the application of Civil engineering principles to improve and maintain the environment to protect human health, nature's beneficial ecosystems and improve environmental-related enhancement of the quality of human life.

They are trained in water quality, water treatment, wastewater management, air pollution control, protecting ecosystems, solid waste management, and related fields.

Some of their responsibilities in the water sector include:

- design and help maintain dams, reservoirs, aqueducts, pumping stations, pipelines, water treatment plants, and other parts of the water supply, delivery and treatment system;
- design and help maintain sewer systems, wastewater treatment plants, water reclamation plants and outfalls for the collection, treatment and disposal of wastewater;
- help a water/wastewater agency and its community decide what to build and where to build it;
- work with environmental engineers and resource planners on cost estimates and planning studies;
- make sure the plans agree with policies and requirements;

The evaluation of the waste assimilation capacity of a stream is of fundamental engineering value. Streams are very important to the general environmental sanitation of any community, it is, therefore, necessary to determine their assimilation capacity in order not to destroy their usage for other environmental purposes

Explaining the problem to optimize

The concentration of dissolved oxygen (DO) is a huge marker of stream disinfection or contamination. The release of waste into a waterway diminishes the DO level and presents an issue of essential significance in the field of water contamination control. The assurance of the DO level in streams frequently takes a progression of information assortment and thorough examination.

A System Dynamics optimization modeling has been joined with hypothetical conditions to show and anticipate the DO levels of a first order stream **(Oba and Sango streams situated inside the area of the University of Ibadan, Nigeria.).** Field information were gathered week by week for 42 weeks to approve the model. The outcomes acquired mirrored the impact of the anthropogenic exercises along the banks of the streams. It has been established that such models can be useful in the prediction of disaster in a body of water.

Explaining the solution

Theoretical backgrounding for DO estimation:

It has been established that the rate of plant respiration is relatively constant in a natural water body and has a simple relationship with the maximum rate of photosynthesis and thus the equation for modeling the DO in streams can be written as:

$$DO_{model} = DO_{max} - C(DO_{max} - DO_{min})$$

$$C = \frac{P_m}{R}$$

Where:

DO_{model} = Predicted/Modeled DO
DO_{max} = Observed Maximum DO deficit on observed diurnal curve
DO_{min} = Observed Minimum DO deficit of observed diurnal curve
C = Photosynthesis to Respiratory ratio
R = Rate of plant respiration, a constant
Pm = Maximum rate of photosynthesis

The diurnal variation of photosynthetic oxygen production **P(t)** follows a similar pattern as incident solar
radiation, and may be represented as:

$$P(t) = P_m sin\left[\frac{\pi}{T}(t-\alpha)\right]$$

Where:

T = period of photosynthetic activity and
α = phase shift of photosynthetic activity

Although the rate of photosynthesis changes over time, for a balanced ecosystem, the average gross photosynthesis oxygen production should be about equal to average plant respiration.

$$P_m \int_0^{T+\alpha} sin\left[\frac{\pi}{T}(t+\alpha)\right] dt = R \int_0^{2\alpha+T} dt$$

Hence:

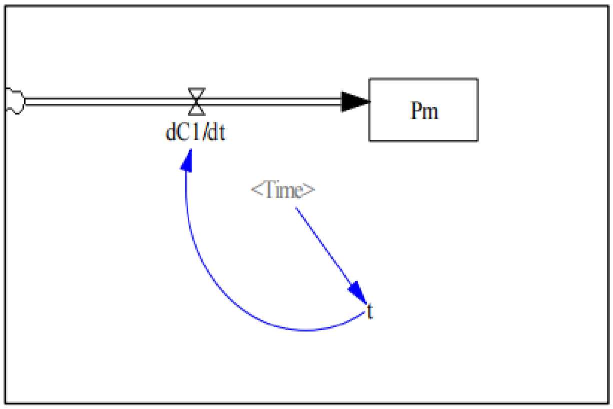
$$C = \frac{P_m}{R} = \frac{\int_0^{T+\alpha} sin\left[\frac{\pi}{T}(t+\alpha)\right] dt}{\int_0^{2\alpha+T} dt}$$

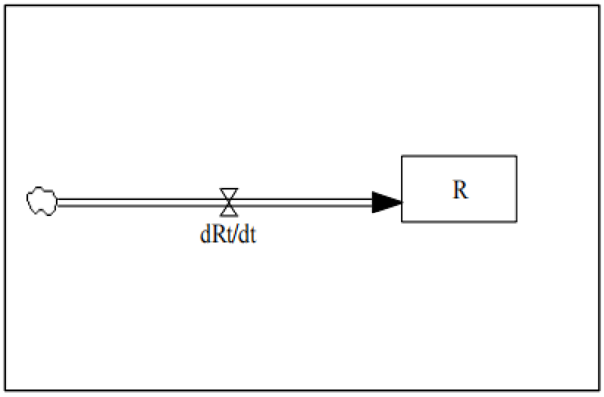
We have established that the required relationship whereby a stream's steady state component of DO content can be determined based on **observed DO data** and **a constant ratio between plant respiration and the maximum rate of photosynthesis.**
Therefore, a modeling method was chosen to acquire an adequate value for this constant ratio C. **(3)**

Dynamic optimization method:

Dynamic optimization is an approach to understanding the nonlinear behavior of complex systems over time using stocks, flows, internal feedback loops, table functions and time delays

Step 1: Equation Modeling





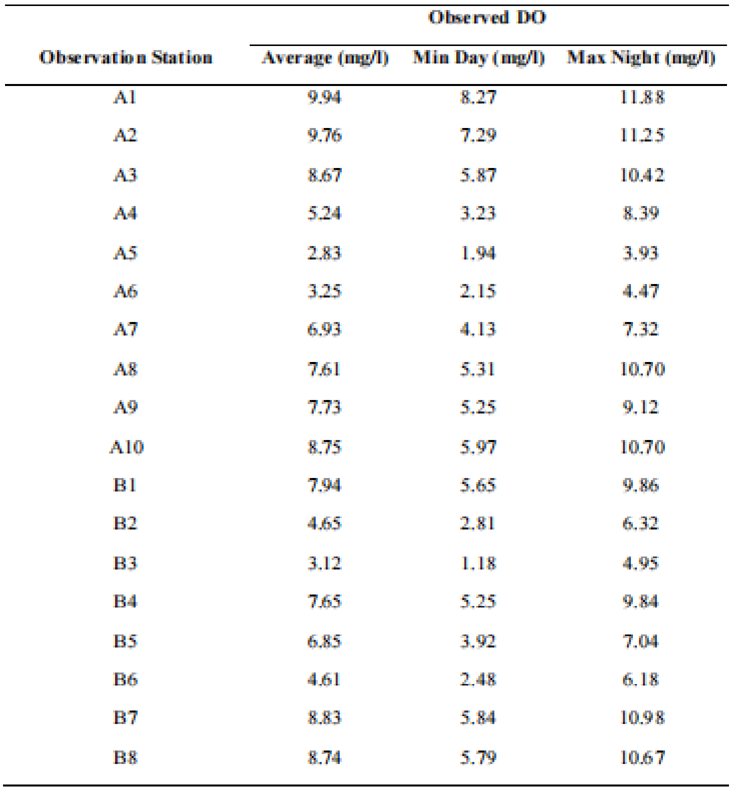
$$P_m \int_0^{T+\alpha} \sin\left[\frac{\pi}{T}(t+\alpha)\right] dt = R \int_0^{2\alpha+T} dt$$

$$C = \frac{P_m}{R} = \frac{\int_0^{T+\alpha} \sin\left[\frac{\pi}{T}(t+\alpha)\right] dt}{\int_0^{2\alpha+T} dt}$$

Step 2: Field Data

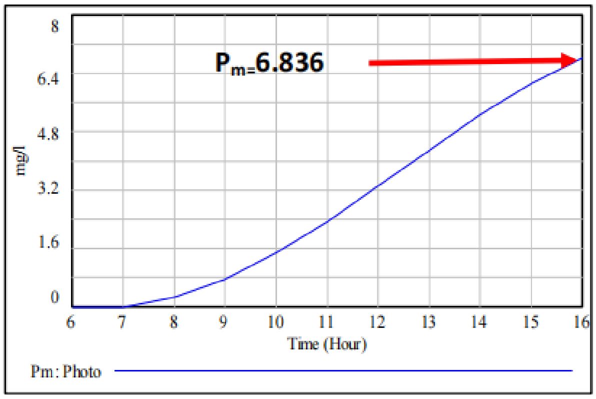
The following data in the table was collected week by week for 42 weeks within the area of Oba and Sango streams situated inside the area of the University of Ibadan, Nigeria.

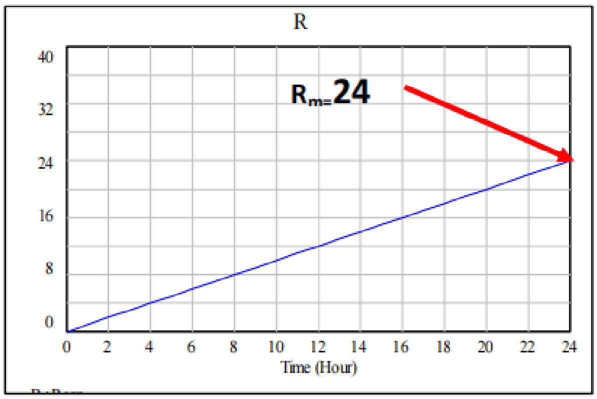
- T=24
- α=6h



Observation Station	Observed DO		
	Average (mg/l)	Min Day (mg/l)	Max Night (mg/l)
A1	9.94	8.27	11.88
A2	9.76	7.29	11.25
A3	8.67	5.87	10.42
A4	5.24	3.23	8.39
A5	2.83	1.94	3.93
A6	3.25	2.15	4.47
A7	6.93	4.13	7.32
A8	7.61	5.31	10.70
A9	7.73	5.25	9.12
A10	8.75	5.97	10.70
B1	7.94	5.65	9.86
B2	4.65	2.81	6.32
B3	3.12	1.18	4.95
B4	7.65	5.25	9.84
B5	6.85	3.92	7.04
B6	4.61	2.48	6.18
B7	8.83	5.84	10.98
B8	8.74	5.79	10.67

Step 3: Implementing Data to the SD Model.





The two previous graphics are result of the integration of respectively the Dividend and the Divisor of the following equation via the Vensim^R modeling platform.

$$C = \frac{P_m}{R} = \frac{\int_0^{T+\alpha} sin\left[\frac{\pi}{T}(t+\alpha)\right]dt}{\int_0^{2\alpha+T} dt}$$

C = 0.285

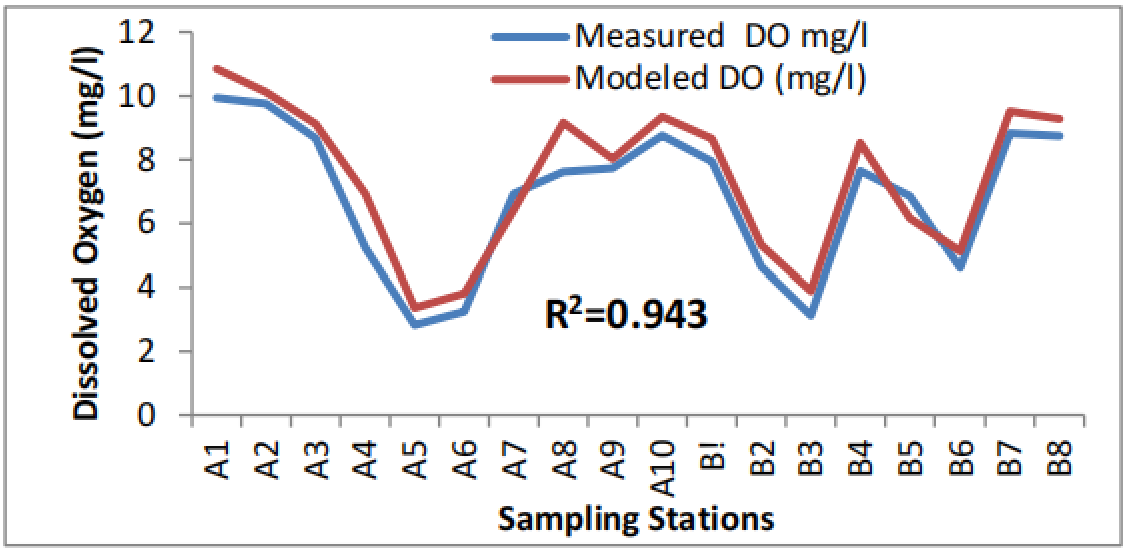
Step 4: Creating the Optimized model.

The following table is the result of multiple calculations according to the equation :

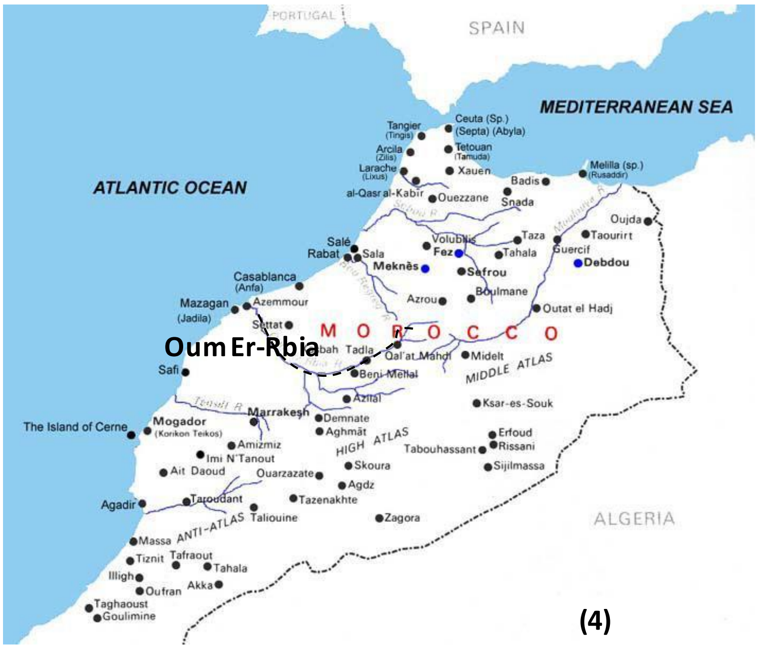
$$DO_{model} = DO_{max} - \mathbf{0.285}(DO_{max} - DO_{min})$$

Observation Stations	**Observed DO** Average DO (mg/l)	Min Day (mg/l)	Max Night (mg/l)	**Modeled DO** (mg/l)
A1	**9.94**	8.27	11.88	**10.85**
A2	**9.76**	7.29	11.25	**10.12**
A3	**8.67**	5.87	10.42	**9.12**
A4	**5.24**	3.23	8.39	**6.92**
A5	**2.83**	1.94	3.93	**3.36**
A6	**3.25**	2.15	4.47	**3.81**
A7	**6.93**	4.13	7.32	**6.41**
A8	**7.61**	5.31	10.70	**9.16**
A9	**7.73**	5.25	9.12	**8.02**
A10	**8.75**	5.97	10.70	**9.35**
B1	**7.94**	5.65	9.86	**8.66**
B2	**4.65**	2.81	6.32	**5.32**
B3	**3.12**	1.18	4.95	**3.88**
B4	**7.65**	5.25	9.84	**8.53**
B5	**6.85**	3.92	7.04	**6.15**
B6	**4.61**	2.48	6.18	**5.13**
B7	**8.83**	5.84	10.98	**9.52**
B8	**8.74**	5.79	10.67	**9.28**

Result Comparison:



Implementation in Morocco



(4)

Oum Er-Rbia river is one of Morocco’s First Order Streams.

And due to the socio-economic importance of this river and the high pollutant caused by the agglomeration and industrial units distributed through the banks and tributaries. Their rejects in the water courses of Oum Er-Rbia can modify the quality of the water and prevent the development of socio-economic activities.

Therefore, a rigorous measure and prediction of DO concentrations in this important water source is crucial. And the previously established Dynamic optimization methodology can analogically be applied in Morocco 2nd biggest river.

Enlargement perspectives for the optimization method

In many of today's economic systems the awareness of sustainability issues is still too low. In order to preserve our planet earth for this and future generations it is essential to use finite and regenerative resources as well as human labor in a sensible way. Yet that transition to a more sustainable economic system can be foreseen using mathematical models, which are referred to as continuous, deterministic dynamical systems. Which are typically described by ordinary differential equations over time. They describe how a system behaves starting from a given initial condition within a specified time period, arriving to the transition from unsustainable to sustainable economic and production system. These models contain a number of parameters that represent external adjustment, which have counterparts in the real world. To find out the best-possible settings of the adjustment variables with respect to some sustainability indicators, methods of linear and mixed-integer nonlinear optimization will be applied. And that is an application of the **Dynamic Optimization method.**

Will a project optimization be more efficient If it’s by a technical office or a big company?

I personally believe that a precise answer would fall into knowing exactly what type of project is being optimized. A technical office would more efficiently work on a specialized topic, material optimization for example. But on the other hand, a big company would have much more resources to apply on a larger and more diverse project!

For the studied case of the optimization of the estimation of DO level in a water stream, a specialized office would do a more efficient job with the right amount of time and resources.

References:

(1) https://www.usgs.gov/special-topic/water-science-school/science/dissolved-oxygen-and-water?qt-science_center_objects=0#qt-science_center_objects

(2) http://www.cotf.edu/ete/modules/waterq3/WQassess4b.html

(3) https://www.researchgate.net/publication/331453913_Model_for_the_Estimation_of_Dissolved_Oxygen_for_First_Order_streams_A_Case_Study_of_Oba_and_Sango_Streams_within_the_Precinct_of_University_of_Ibadan_South-West_Nigeria

(4) https://maps-morocco.com/morocco-river-map